We thank the reviewer for the time she/he took and for the comments provided, which will help us to improve the manuscript. A pointwise reply to the reviewer's comment is given below.

Specific comments

1.) *The model temperature forcing is not clear. For example, what is the vertical structure of the forcing? What exactly is T_1 and T_new? I'm not sure what updated temperature means. Is this a restoration temperature field like in the Held-Suarez model??*

The temperature T_{New} is the final temperature based on all three temperature components and is used as model input to which the dynamical core equilibrates. In temperature T_1 only the global mean temperature and the meridional temperature gradient is altered/ updated. The azonal temperature gradient is not yet included (as its influence on global-mean temperature is zero as opposing azonal temperature anomalies cancel each other out).
We will rewrite it in: $T_1(\phi, \lambda)$ is the altered temperature with changed global mean temperature and meridional temperature.

2.) *Could you include more plots of the zonal asymmetries to support the discussion? I would also put less emphasis on the fact that increasing the meridional temperature gradient increases the jet strength, since this is to be expected from the thermal wind balance.*

We agree with the reviewer and will include 3D plots with all different azonal components used in the experiments in order to support the discussion:

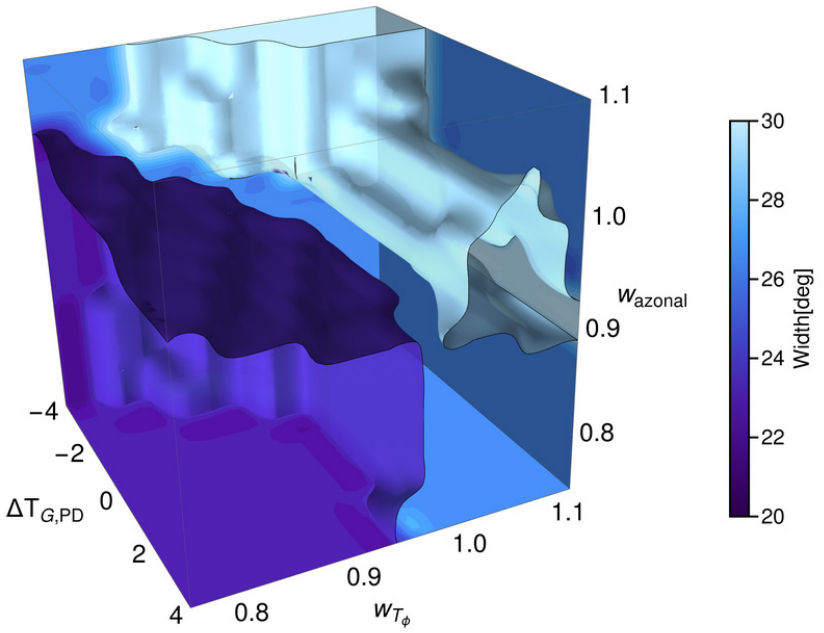

Figure 1 Width of the Hadley cell in dependence of w_{T_ϕ} and w_{azonal} and $\Delta T_{G,PD}$, whereby $\Delta T_{G,PD}$ is the difference between the present day temperature and the changed global mean temperature.

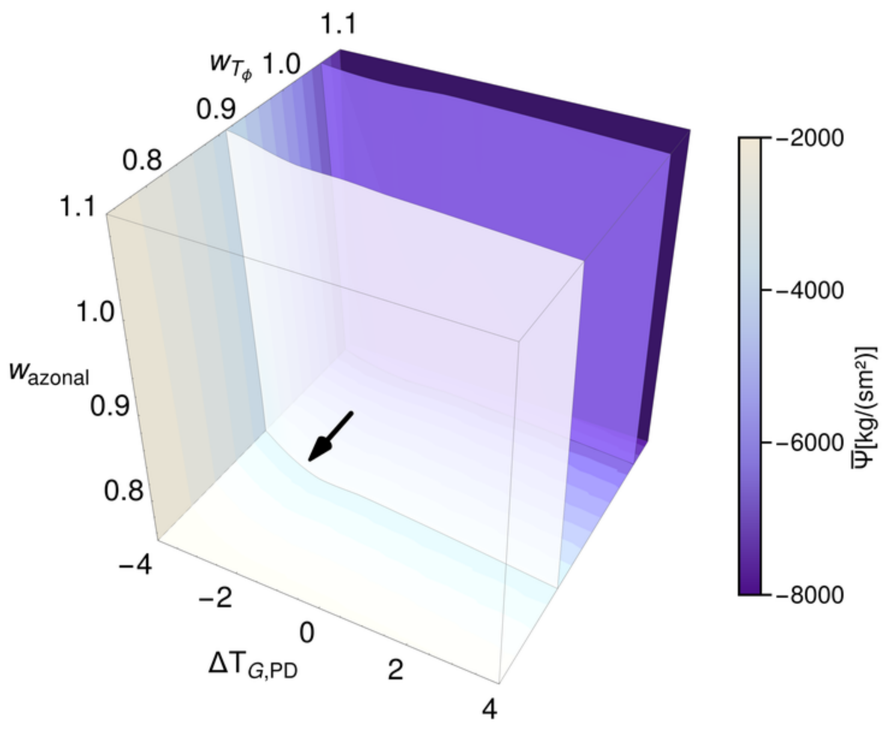

Figure 2 Strength of the Hadley cell in dependence of w_{T_ϕ} and w_{azonal} and $\Delta T_{G,PD}$, whereby $\Delta T_{G,PD}$ is the difference between the present day temperature and the changed global mean temperature. The arrow points in the direction of the strongest gradient.

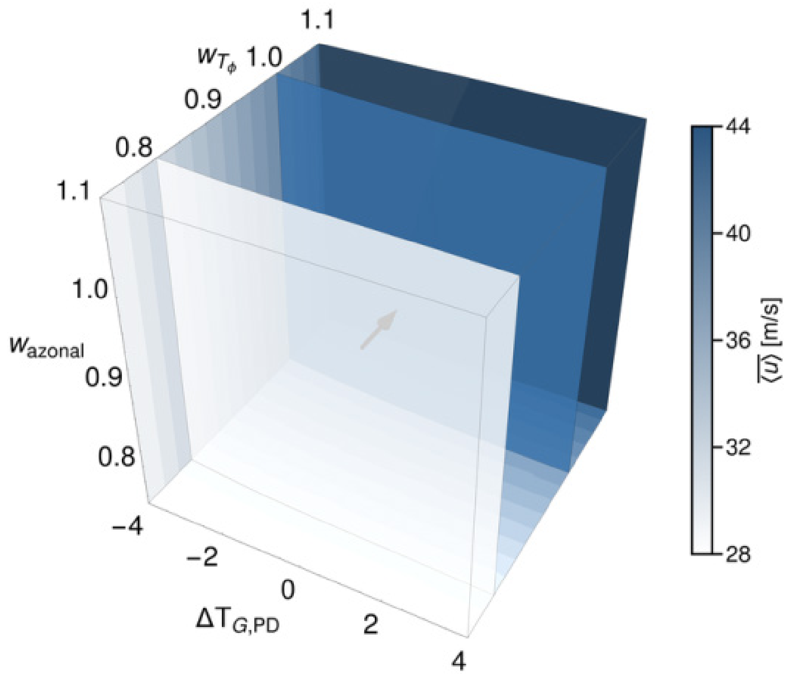

Figure 3 Jet stream strength defined by the meridional average of the zonal mean zonal wind velocity (⟨u⟩ ̅ between 10°N and 80°N at a height of 9000 m in dependence of w_{T_ϕ} and w_{azonal} and $\Delta T_{G,PD}$, whereby $\Delta T_{G,PD}$ is the difference between the present day temperature and the changed global mean temperature. The arrow points in the direction of the strongest gradient.

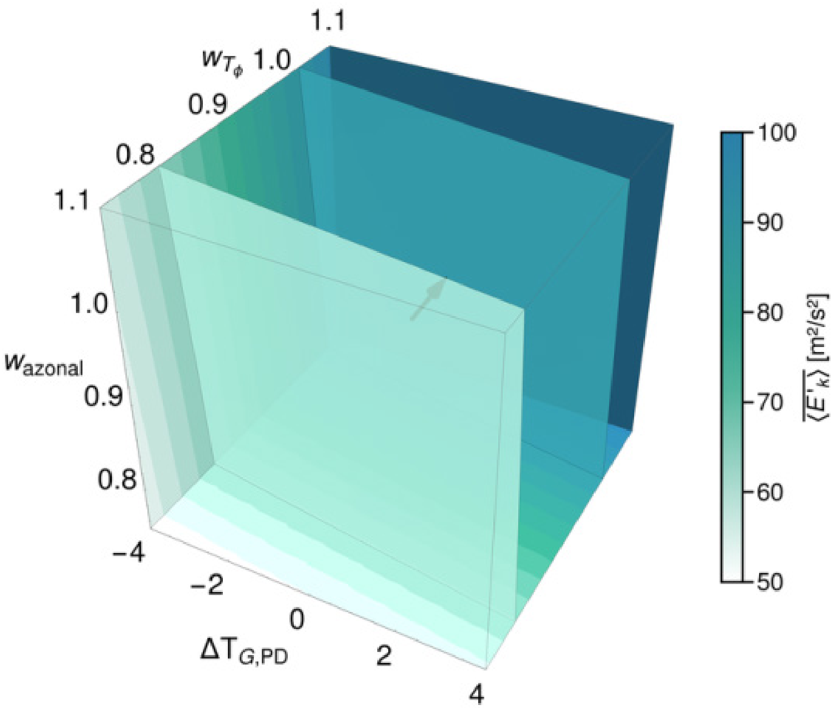

Figure 4 Strength of storm track activity in dependence of w_{T_ϕ} and w_{azonal} and $\Delta T_{G,PD}$, whereby $\Delta T_{G,PD}$ is the difference between the present day temperature and the changed global mean temperature. The arrow points in the direction of the strongest gradient.

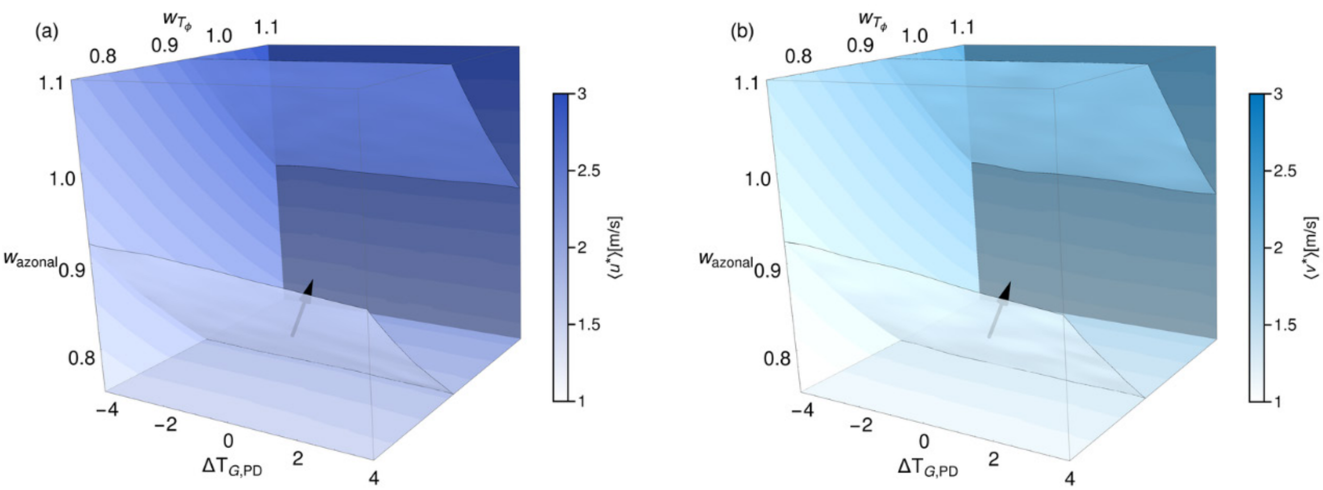

Figure 5 Strength of planetary waves $\langle u^* \rangle$ and $\langle v^* \rangle$ in dependence of w_{T_ϕ} and w_{azonal} and $\Delta T_{G,PD}$, whereby $\Delta T_{G,PD}$ is the difference between the present day temperature and the changed global mean temperature. The arrow points in the direction of the strongest gradient.

We will put less emphasis on the fact that increasing meridional gradient increases the jet strength.

3.) *How is the separation into planetary and synoptic scale waves done? E.g. are you using the Lanczos filter or just running mean? Also, the planetary wave definition uses departures from the zonal mean, but synoptic eddies are included in this. Discussion of stationary wave changes would be helpful.*

In the atmosphere model Aeolus 1.0, the synoptic waves are parameterized in terms of the large scale wind field which is the basic idea of a statistical-dynamical method. A full description can be found in Coumou et al. (2011). The equations for planetary waves are derived in Molnos et al. (2016). We will add this info in the revised manuscript.

For comparison, we calculated planetary and synoptic waves from zonal and meridional wind fields using ERA-Interim data. The synoptic waves were calculated by using a 2.5-6 bandpass filter. The planetary waves are the azonal deviations from the monthly-mean zonal mean wind field.

4.) *Using a vertically integrated EKE would be more robust, in that it would eliminate the possibility that the changes are due to the EKE maximum moving vertically.*

We agree with the reviewer and used a vertical integrated EKE. The results are qualitatively similar (Fig. 5).

5.) *Some key literature on GCM modelling of the atmospheric response to changes in thermal structure is missing (e.g. work by Tapio Schneider, Paul O'Gorman, Amy Butler, etc.)*

We agree with the reviewer and will include additional literature:

In the introduction summary we will include:
Moreover, recent studies using dry and most idealized general circulation models suggest that the strength and extent of the Hadley cell depends on static stability, meridional temperature gradient and the tropopause level (Schneider and Walker, 2008; O'Gorman, 2011; Levine and Schneider, 2015).

In the storm tracks section we will include:
O'Gorman and Schneider (2008) examined the response of storm tracks to different climate conditions simulating an aquaplanet model and by changing the longwave

optical thickness in the radiation scheme of the GCM (representing variations in greenhouse gas concentrations). They found that eddy kinetic energy has a maximum for a climate with the global-mean temperature similar to that of present-day-climate. Lower or higher global-mean temperatures lead to significantly smaller values. In addition, they observed that the eddy kinetic energy increases monotonically with the meridional insolation gradient (representing changes in, for example, high-latitude surface albedo).

Similarly, Pfahl et al. (2015) investigated the behavior of extratropical cyclones under strongly varying climate conditions using idealized climate model simulations in an aquaplanet setup. They changed the meridional insolation gradient together with the longwave optical thickness with shortwave parameters held constant. They found that the maximum of eddy kinetic energy is reached at a global mean temperature slightly warmer than present-day climate.

These results are different to our results, where no such peak in EKE can be observed. The different results may be explained by the different techniques applied to simulate higher global mean temperature. In our study, we directly change the temperature, whereas Pfahl et al. change the longwave optical thickness with shortwave parameters held constant, which represents variations in longwave absorbers like carbon dioxide and water vapor. These changes could also change the meridional and azonal temperature gradient leading to different results.

However, we also observe a strong positive dependence between temperature gradient and Eddy kinetic energy.

In the Hadley cell section, we will include:

Seo et al. (2014) investigated possible drivers of the Hadley cell such as the meridional temperature gradient, gross static stability and tropopause height using the Coupled Model Intercomparison Project Phase 5 (CMIP5). Consistent with our results, they found a robust dependence between meridional temperature gradient and the strength of the Hadley cell in winter: A decreased meridional temperature gradient leads to a weakening of the Hadley cell.

In addition, D'Agostino et al. (2017) analyzed and compared the Hadley cell during the last glacial maximum to global warming scenarios (RCP4.5 and RCP8.5) with a focus on dependence on subtropical stability, near-surface meridional potential temperature gradient, and the tropical tropopause level. They concluded that the meridional temperature gradient is a major driver for Hadley cell changes.

However, in both studies the atmospheric composition in terms of anthropogenic aerosols is changed and hence not only the meridional temperature gradient changes but also the global mean temperature and the azonal temperature gradient. This makes it difficult to attribute changes in the Hadley cell to one temperature component only.

Specific comments

1.) *P2 L22:positive trend -> strengthening trend?*
Thanks, we will correct this.

2.) *P2 L24: reference Storm tracks play a crucial role in modulating precipitation in the Earth system.*
Thanks, we will add the references (Raible *et al.*, 2007; Hawcroft *et al.*, 2012; Lehmann and Coumou, 2015)

3.) *P3 L5: the Hadley Cell*
Thanks we corrected it.

4.) *P4 L1: chapters -> sections*
Thanks, we corrected it.

5.) *P5 L4: using 300 hPa to diagnose the jet location: no results for the jet latitude are presented*
We removed this sentence.

6.) *P5 L21: orange line -> dashed line?*
Yes dashed line, we will correct this.

7.) *P5 L23: please clarify what you mean by "zero-crossings"*
Zero-crossing refers to the point in the graph where the function f(x) crosses the x=0 line. We will rewrite this part in the revised manuscript.

8.) *P7 L12: vice versa: it is not clear to me what exactly this is referring to*
We want to make the statement that if the azonal temperature gradient is smaller than the meridional temperature gradient, the strength of the planetary waves increases faster with higher azonal temperature gradient. We will rewrite this part in the revised manuscript.

9.) *P7 L12: please clarify what you mean by "wave-shaped structure"*
Wave-shaped structure means that the mean strength of the planetary waves varies in a curved way depending on meridional temperature gradient and azonal temperature gradient. We will rewrite this part.

10.) *P9 L19: : : :temperature gradient in this study.*
Thanks, we will add that.

11.) *P10 L1: gradients*

Thanks, we will correct that.

12.) P10 L13: Arctic

Thanks, we will correct that.

13.) P10 L31: : : :observed by previous studies, which: : :

Thanks we will add this.

14.) P11 L1: In contrast -> In addition

We will change this.

15.) P11 L2-3: please clarify what you mean by this sentence

This sentence means that the Hadley cell might have a longitudinal dependence (due to land masses and ocean), which can explain the dependence of the Hadley cell width on the azonal component. We will rewrite this part.

16.) Fig 2, 5: Please improve the colour scale

We will improve the colorbar (as shown in the response of reviewer 1)

17.) Fig 5: no label on y axis

Fig 5 is going to be replaced by the 3-D version that is shown in the response to reviewer #1.

References:

Coumou, D., Petoukhov, V. and Eliseev, A. V. (2011) 'Three-dimensional parameterizations of the synoptic scale kinetic energy and momentum flux in the Earth's atmosphere', *Nonlinear Processes in Geophysics*, 18(6), pp. 807–827. doi: 10.5194/npg-18-807-2011.

D'Agostino, R., Lionello, P., Adam, O. and Schneider, T. (2017) 'Factors controlling Hadley circulation changes from the Last Glacial Maximum to the end of the 21st century', *Geophysical Research Letters*, 44, pp. 1–7. doi: 10.1002/2017GL074533.1.

Hawcroft, M. K., Shaffrey, L. C., Hodges, K. I. and Dacre, H. F. (2012) 'How much Northern Hemisphere precipitation is associated with extratropical cyclones?', *Geophysical Research Letters*, 39(24), pp. 1–7. doi: 10.1029/2012GL053866.

Lehmann, J. and Coumou, D. (2015) 'The influence of mid-latitude storm tracks on hot, cold, dry and wet extremes.', *Scientific reports*, 5, p. 17491. doi: 10.1038/srep17491.

Levine, X. J. and Schneider, T. (2015) 'Baroclinic Eddies and the Extent of the Hadley Circulation : An Idealized GCM Study', *Journal of Atmospheric Sciences*, 72, pp. 2744–2761. doi: 10.1175/JAS-D-14-0152.1.

Molnos, S., Eliseev, A. V., Petri, S., Flechsig, M., Caesar, L. and Petoukhov, V. (2016) 'The

Dynamical Core of the Aeolus Statistical - Dynamical Atmosphere Model : Validation and Parameter Optimization', *Geoscience Model Developement Discussion*. doi: 10.5194/gmd-2016-263.

O'Gorman, P. A. (2011) 'The Effective Static Stability Experienced by Eddies in a Moist Atmosphere', *Journal of Atmospheric Sciences*, 68, pp. 75–90. doi: 10.1175/2010JAS3537.1.

O'Gorman, P. A. and Schneider, T. (2008) 'Energy of Midlatitude Transient Eddies in Idealized Simulations of Changed Climates', *Journal of Climate*, 21, pp. 5797–5806. doi: 10.1175/2008JCLI2099.1.

Pfahl, S., O'Gorman, P. A. and Singh, M. S. (2015) 'Extratropical Cyclones in Idealized Simulations of Changed Climates', *Journal of Climate*, 28, pp. 9373–9392. doi: 10.1175/JCLI-D-14-00816.1.

Raible, C. C., Yoshimori, M., Stocker, T. F. and Casty, C. (2007) 'Extreme midlatitude cyclones and their implications for precipitation and wind speed extremes in simulations of the Maunder Minimum versus present day conditions', *Climate Dynamics*, 28(4), pp. 409–423. doi: 10.1007/s00382-006-0188-7.

Schneider, T. and Walker, C. C. (2008) 'Scaling Laws and Regime Transitions of Macroturbulence in Dry Atmospheres', *Journal of Atmospheric Sciences*, 65, pp. 2153–2173. doi: 10.1175/2007JAS2616.1.

Seo, K., Frierson, D. M. W. and Son, J. (2014) 'A mechanism for future changes in Hadley circulation strength in CMIP5 climate change simulations', pp. 5251–5258. doi: 10.1002/2014GL060868.Received.

Shaw, T. A. and Voigt, A. (2015) 'Tug of war on summertime circulation between radiative forcing and sea surface warming', *Nature Geoscience*, 8(7), pp. 560–566. doi: 10.1038/ngeo2449.